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GEORGE C. MARSHALL **SPACE
FLIGHT
CENTER**

FAILURE ANALYSIS
OF
STRUTHERS-DUNN S2GP7.25-73D
RELAY

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OF STRUTHERS-DUNN S2GP7.25-73D
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I. INTRODUCTION

One Struthers-Dunn relay, part number FC-1-188, type number S2GP7.25-73D, manufactured to MSFC-SPEC-339/73D, was received for failure analysis. The date code is 7643 and the serial number is 52. This relay had been installed in the Range Safety Command Decoder, S/N 402, by AVCO. After Acceptance Test Procedure Vibration Testing, Command Number 1 was sent but no response was received. AVCO concluded that relay, K1, was stuck in the normally closed position. The relay was removed from the assembly and tested again for operation. Operation appeared to be normal. The relay was then forwarded to this laboratory for failure analysis.

II. PURPOSE

The purpose of this analysis was to attempt to determine the cause of failure of this relay.

III. ANALYSIS

The following tests and examinations were performed in an attempt to detect the failure:

- a. X-ray in three planes.
- b. Visual and microscopic examination, especially of the header, glass seals and pins.
- c. Particle Impact Noise Detection test in three planes.
- d. Functional electrical test to verify operation.
- e. Complete electrical characterization tests.

The relay passed all the above tests and examinations with no discrepancies noted.

The relay was prepared for monitored vibration. No anomalies were noted during vibration, but when post-vibration electrical tests were made, the relay was again inoperative as in the original failed condition.

The relay was thoroughly examined on a real time X-ray system while in the failed condition. Particular attention was given the space between the armature and the pole piece to determine if contamination may be present which would prevent the relay from operation. None was visible on the X-ray

system, operation of the relay was attempted. No visible movement of the armature was observed.

All previous tests and inspections had not revealed any evidence of particles or contamination in the relay. Therefore, the most probable cause appeared to be in alignment or adjustment. Since the manufacturer is equipped to make precise measurements of these parameters, it was decided to send the relay to Struthers-Dunn for continuation of the failure analysis.

The relay was opened by Struthers-Dunn and what appeared to be a particle was observed between the armature and pole piece. Struthers-Dunn personnel inserted a piece of paper between the armature and pole piece to dislodge the contamination. After insertion and withdrawal of the paper, the relay operated properly. Since contamination was observed upon opening of the relay by Struthers-Dunn, and critical alignment and adjustment measurements were not required, Struthers-Dunn was directed to return the relay to MSFC for completion of the failure analysis.

Upon receipt by this laboratory, a thorough microscopic examination of the interior of the relay was performed. Some contamination was observed; however, no magnetic particles were found of sufficient size to render the relay inoperative.

The relay was completely disassembled and all parts examined microscopically for wear, interference, or any anomaly which could cause binding or prevent the relay from operating. Figure 1 shows a typical armature relay design.

Two anomalous conditions were noted during the disassembly and inspection:

a. The armature pivot bearing engaging the back stop. Figure 2 shows the armature and pivot bearing assembly. Figure 3 shows the pivot bearing which engages the frames. This pivot bearing has a normal shape and proper undercut at the shoulder to prevent binding. Figure 4 shows the defective pivot bearing with slivers of bearing metal pushed into the undercut. Upon probing these slivers, it was noted that they were attached only on one end and were free to move.

The armature was mounted so that a cross-section could be made to show the undercut in the pivot bearings. Figure 5 shows the cross-section of the pivot bearing with the normal undercut. Figure 6 shows the defective pivot bearing cross-section. Figures 7 and 8 are magnifications of the undercuts of the pivot bearing after etching to show the grain structure.

Note the metal sliver in the cross-section in the undercut area indicating a dull tool, and also the workhardening of the material.

The defective pivot bearing and a sliver were subjected to EDAX X-ray analysis to verify that the sliver was the same material as the pivot bearing. The X-ray spectra of both the pivot bearing and the sliver were identical, figures 9 and 10, thus verifying that the slivers were from the pivot bearings.

b. The back stop holes showed evidence of burrs which could cause binding. This condition is shown in figures 11, 12, and 13. Figures 14 and 15 show a deburred hole which was on the frame.

Telephone inquiries were made to the manufacturer relative to the controls imposed on the relay pivot bearing manufacturing. It appears from these discussions that adequate checks for tool wear, receiving inspection, and acceptance testing is required by the manufacturer. As a part of acceptance testing, the relays are subjected to 100% vibration testing which would normally have detected the failure mechanism in the defective relay.

History data was reviewed to determine if similar failures have occurred in the Struthers-Dunn relays. No similar failures were found.

A visit was made to the Struthers-Dunn plant to review the manufacturer's inspections and controls, and to inspect pivot bearings in the manufacturer's stock. The manufacturers inspections and controls appeared to be adequate.

Approximately 1080 pivot bearings were inspected using a double sampling plan with a 0.4 acceptable quality level (AQL) in accordance with MIL-STD-105D. The first sample was to accept the lot with two rejects and reject the lot with five rejects and the second sample was to accept the lot with six rejects and reject the lot with seven rejects. The sample size was 315 for each sampling for a total of 630 samples. In the first sample, one pivot bearing was rejected because of no undercut and in the second sample two pivot bearings were rejected, one for no undercut and the other for a sliver as in the failed relay.

Approximately 450 additional pivot bearings were inspected. Of these, two were rejected, one for a sliver in the undercut and the other with a "V" shaped undercut.

All samples passed the 0.4 AQL sampling plan. The failures found are considered typical of automatic screen machine operation.

IV. CONCLUSIONS

It is concluded that the failure of this relay resulted from a manufacturing defect which escaped through the inspections and tests performed by the manufacturer. The cause of the failure was binding of the armature caused by metal slivers in the undercut of the pivot bearing. Although the undercut in the defective pivot bearing was less than desirable, it was sufficient to eliminate binding had the metal slivers not been present. Further, it is believed that the slivers were caused by a dull tool creating burrs during the machining operation. The burrs on the back stop could have contributed to the failure, however, X-ray analysis did not show evidence of the bearing material on the burred edge.

It is further concluded that the particle noted by Struthers-Dunn personnel upon opening the relay was probably generated during opening, and upon probing, sufficient side force was generated which freed the armature from binding, thus allowing the relay to operate.

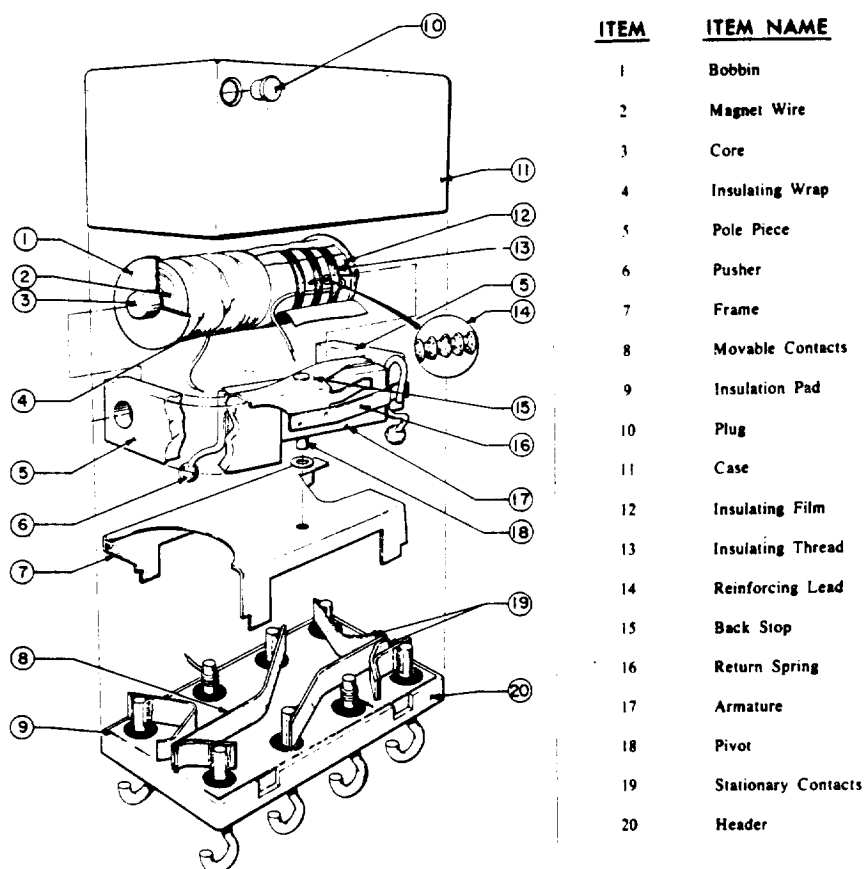


Figure 1. Typical Armature Relay Design



Figure 2. Armature of Failed Relay

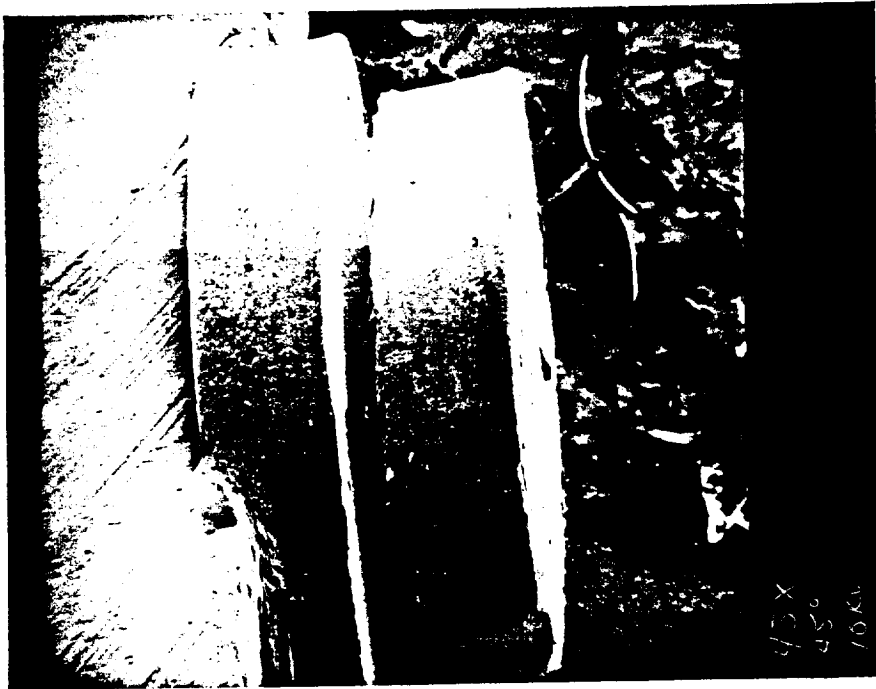


Figure 3. Normal Pivot Bearing of Relay Armature (43X)

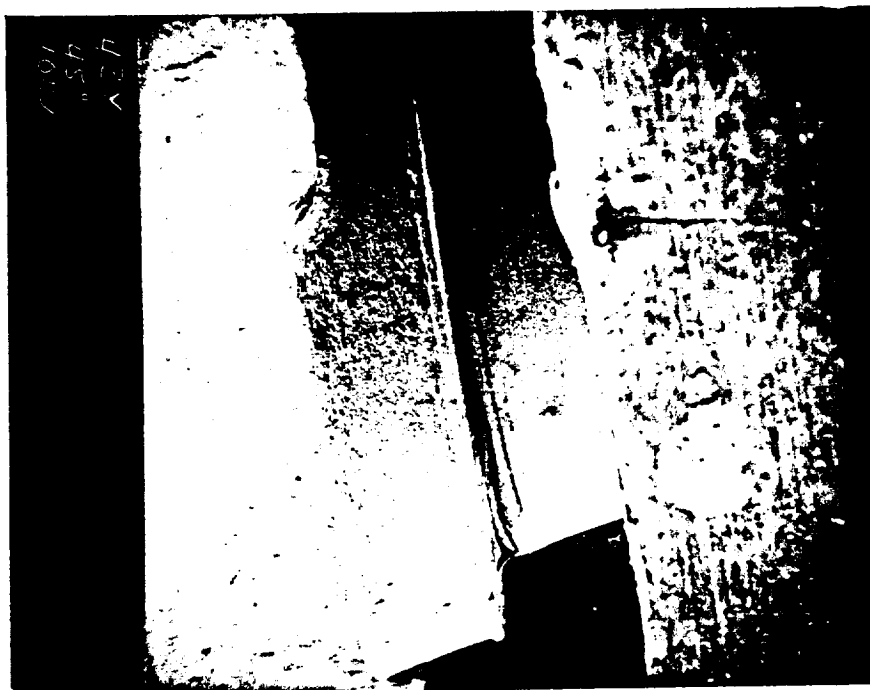


Figure 4. Defective Pivot Bearing of Relay Armature (43X)

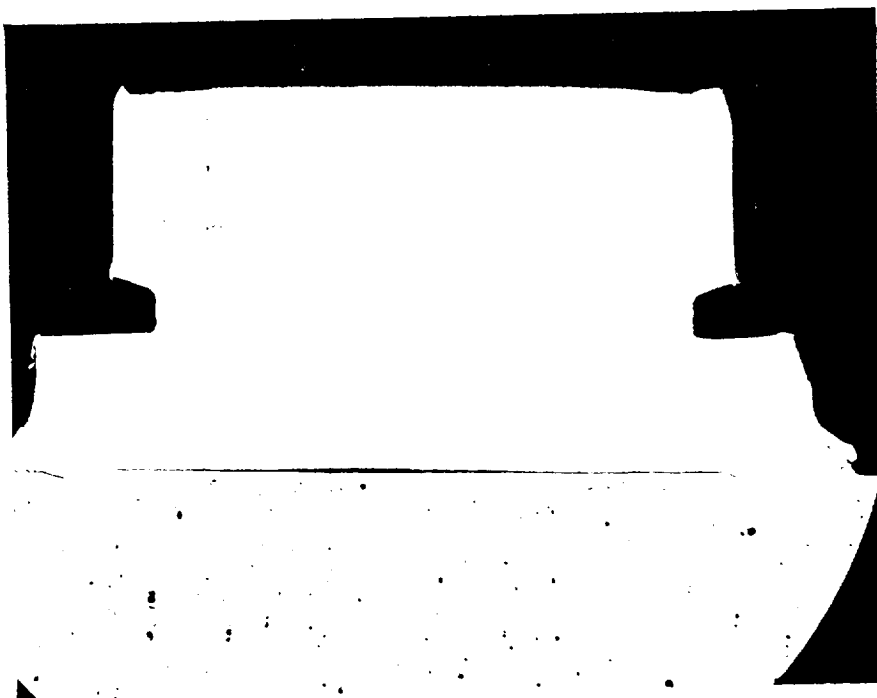


Figure 5. Cross-section of Normal Pivot Bearing of Relay Armature (52X)

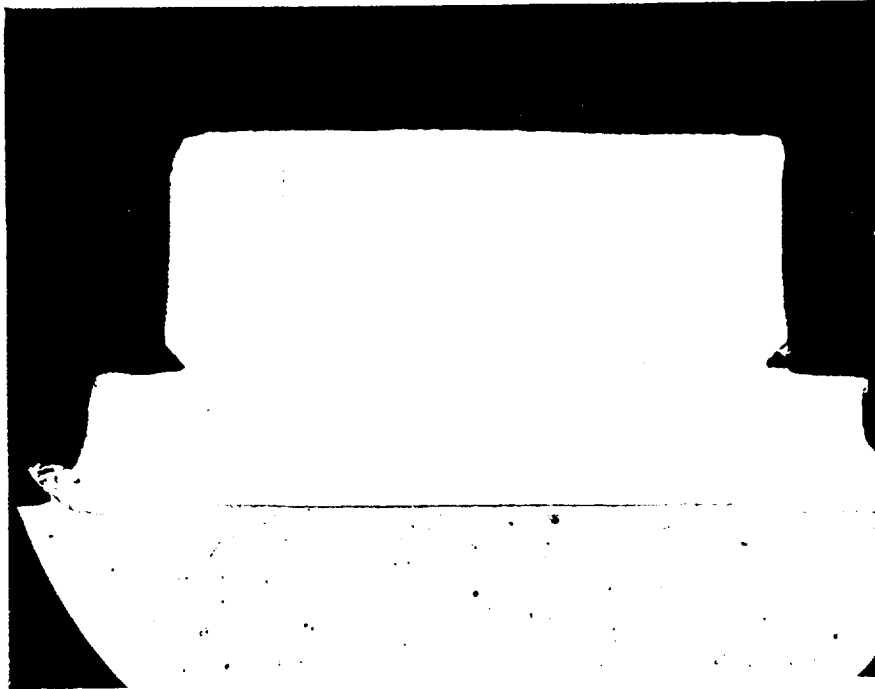


Figure 6. Cross-section of Defective Pivot Bearing of Relay Armature (52X)

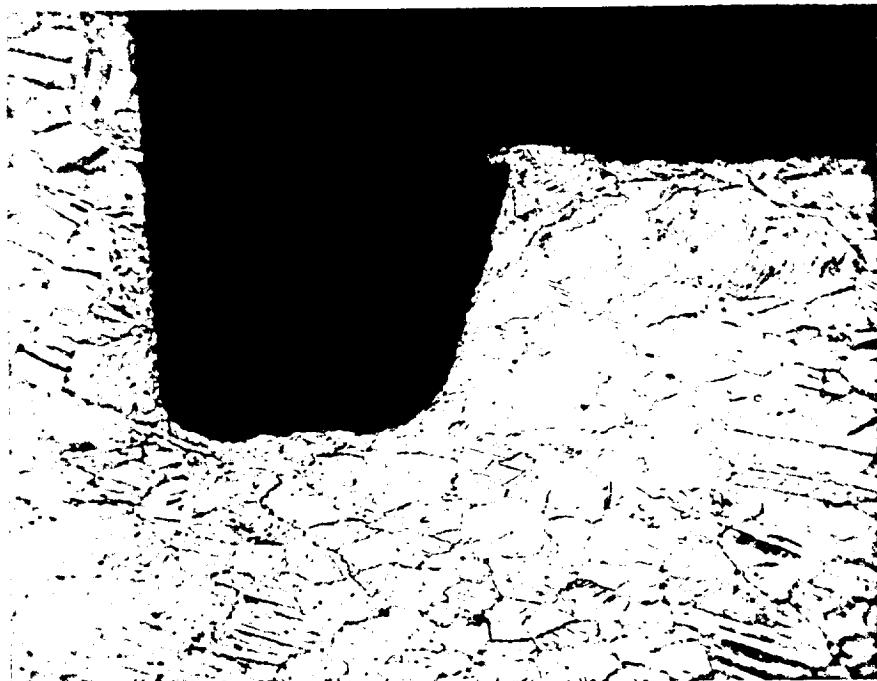


Figure 7. Magnification of Undercut Cross-section of Normal Pivot Bearing of Relay Armature After Etching (300X)

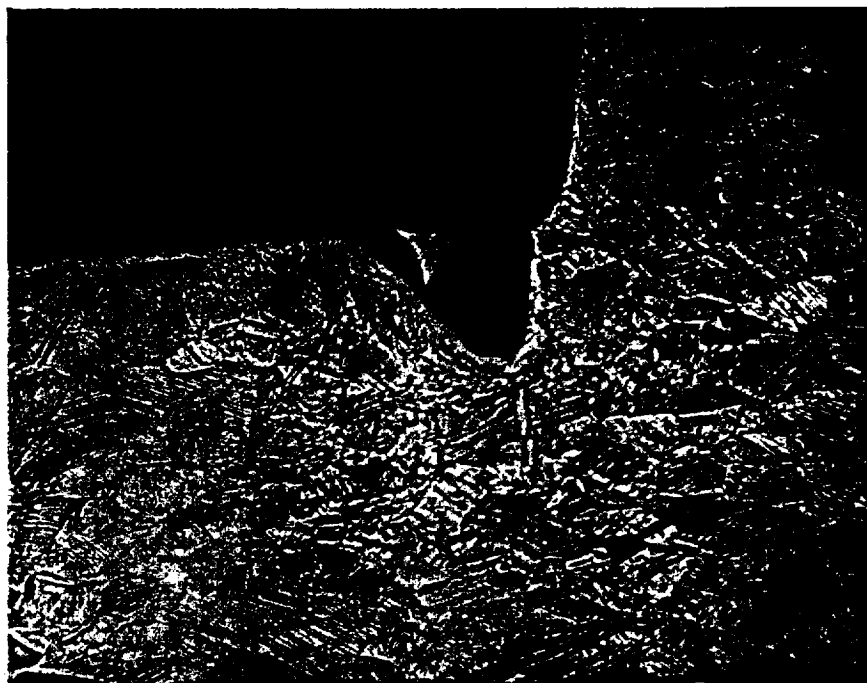


Figure 8. Magnification of Undercut Cross-section of Defective Pivot Bearing of Relay Armature After Etching (300X)

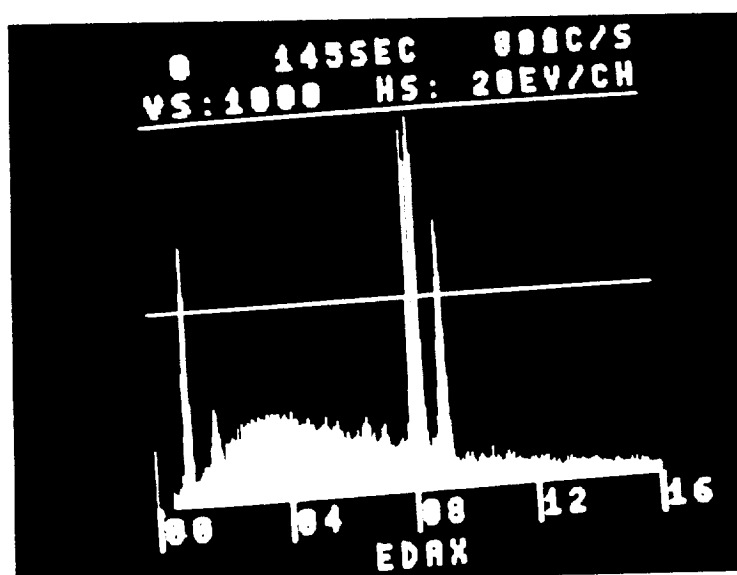


Figure 9. EDAX Analysis of Pivot Bearing

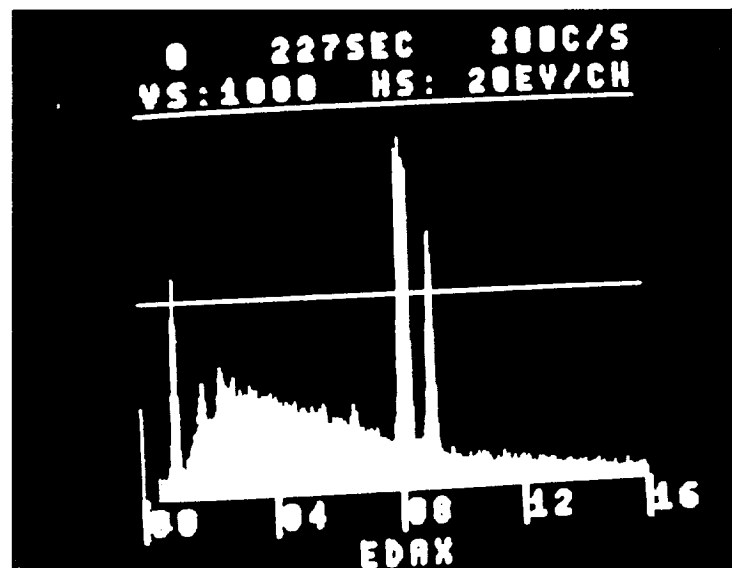


Figure 10. EDAX Analysis of Metal Sliver

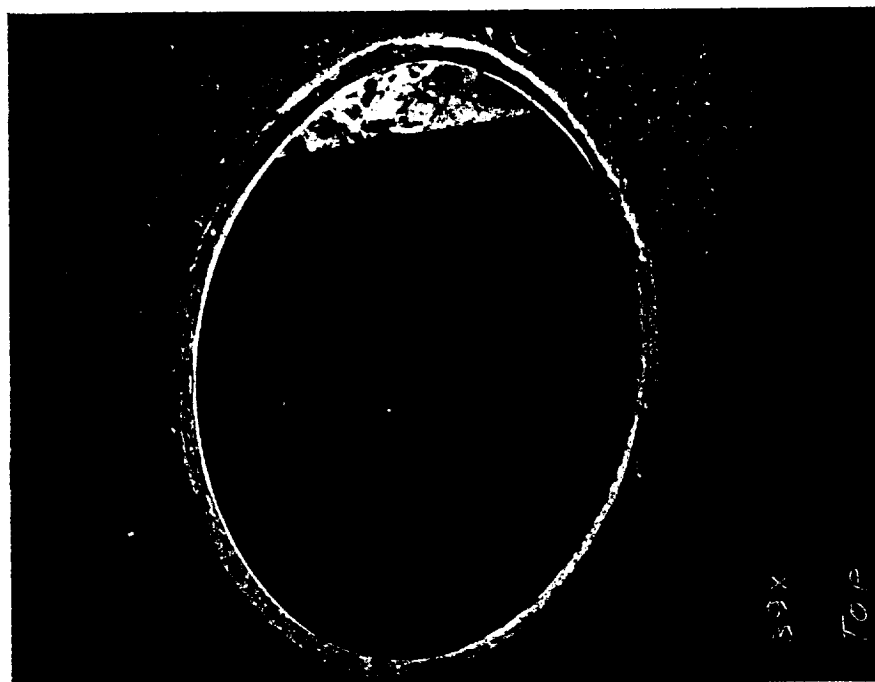


Figure 11. Armature Side of Bearing Journal of Defective Pivot Bearing (39X)



Figure 12. Armature Side of Bearing Journal of Defective Pivot Bearing (50X)

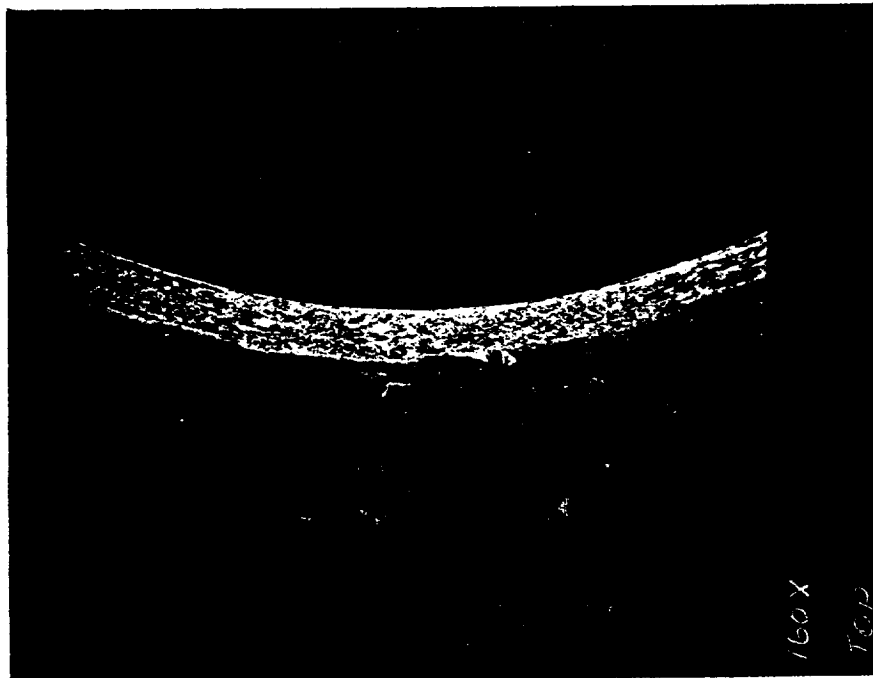


Figure 13. Magnified View of Armature Side of Bearing Journal of Defective Pivot Bearing (160X)

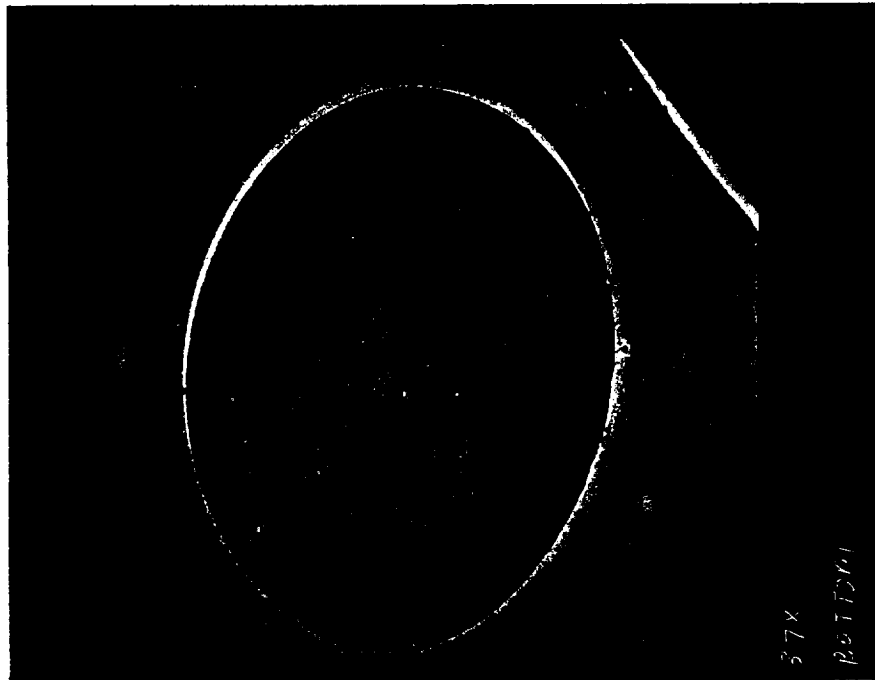


Figure 14. Armature Side of Bearing Journal of Good Pivot Bearing (37X)



Figure 15. Magnified View of Armature Side of Bearing Journal of Good Pivot Bearing (375X)

